# ENGINEERED AND NATURAL NEW MEXICO ANALOGUES FOR GEOLOGIC ISOLATION OF HEAT GENERATING WASTE IN ROCK SALT

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*Underground nuclear detonations are confidence-inspiring engineered analogues for safe confinement of heat generating waste in geologic repositories. An excellent domestic example is the 3kt Gnome test (part of the Plowshare series) in salt beds east of Carlsbad, New Mexico. Radioactively laced steam vented briefly and dispersed quickly to innocuous concentrations immediately after the ~400m deep nuclear test, but regular monitoring since then has not detected releases of harmful materials in almost 50 years. Gnome therefore presents an extreme, beyond-worst-case scenario by comparison with the anticipated performance of the WIPP (~12km northeast), and it augurs well for contemplated repositories in salt for heat generating waste.*

*Igneous dikes prove the generally insignificant effects of significant heat sources on surrounding rocks. Specifically, vertical Tertiary basalt dikes cutting through horizontal Permian salt beds in Germany and New Mexico altered the host rock only along narrow rims and induced only very localized and insignificant fluid movement. The invaded rock salt remained impermeable even to gas through millions of years as demonstrated by pockets of $CO_2$ under high pressure that potash mines encounter occasionally near the dikes.*

*Repositories for heat generating waste will be suitable for their purpose and perform effectively if their locations are selected based on scientific and technical criteria rather than parochial arguments and demagoguery posing as concern for safety. Local natural and engineered analogues demonstrate the suitability of the salt beds near Carlsbad for isolating all categories of dangerous materials (classified as radioactive or not, heat generating or not) beyond rational or honest doubt.*

## INTRODUCTION

Assertions about the long-term behavior of geologic repository systems are frequently based on inappropriate projections from the results of laboratory-scale investigations to full-scale models. Geoscientists however insist on observations of natural features, events, and processes as the indispensible ingredients of site characterization and conclusive evidence of long-term safety.[1]

A presentation to the Blue Ribbon Commission on America's Nuclear Future[2] included these salient points:

- Heat generated by the waste affects geochemical processes and the rates of degradation of engineered barriers
- Extensive modeling is necessary to predict repository performance

This brief essay advances the counter-argument that:

- Heat in many instances has negligible effects on the confinement capability of host rock, based on observations of natural and engineered analogues
- Worst-case analogues bound repository performance well within reasonable limits, rendering excruciatingly detailed modeling and complete understanding of miniature-scale processes unnecessary.

## I. NATURAL GEOTHERMAL EFFECTS

Outside of areas of regional metamorphism caused by massive igneous intrusions or by deep subsidence of crustal rocks into domains of intense pressure and temperature, e.g., at plate boundaries, alterations in rocks surrounding local heat sources (contact metamorphism) remain small and narrow. Evidence from fossil hydrothermal systems, for example, indicates that mineral alteration resulting from the flow of hot fluids through fractures extends only a few centimeters from the fracture wall into the matrix.[3]

Very deep wells penetrate deeper than 9km where they encounter temperatures 200°C and higher.[4] Even under such extreme conditions, reservoir rocks confine toxic and combustible fluids (hydrocarbons) up to several hundreds of millions of years with quite adequate integrity. Maximum surface temperatures of ~10 year-old used nuclear fuel and high-activity waste canisters, by comparison, are expected to range from ~140 to ~240°C for <100 years.[5]

Of course it should, but unfortunately does not in today's environment of fashionable nuclear illiteracy, go without saying "that geothermal energy is just another name to describe the radioactivity of our planet."[6]

### I.A. Igneous dikes

Narrow linear bodies of magma intruded from below into host rocks above and solidified in place are common features in a variety of geologic environments. One of the best-known dike swarms radiates from the neck of an old volcano known as Shiprock in northwestern New Mexico. Dikes are also widespread in the vicinity of the Spanish Peaks in southeastern Colorado where several are easily visible from Interstate Highway 25. A basalt dike exposed in central New Mexico is shown below (Fig.1).

Fig.1, Igneous dike in road cut, US 380, Lincoln County, west of Capitan, NM

### I.B. Dikes in evaporite deposits

Vertical Tertiary (~15-30my) basalt dikes cutting through horizontal Permian (>250my) salt beds in Germany and New Mexico altered the host rock only along narrow rims and induced only very localized and insignificant fluid movement. The invaded rock salt remained impermeable even to gas through millions of years as demonstrated by pockets of $CO_2$ under high pressure (Fig.2) that potash miners encounter occasionally near the dikes. While the magma itself is assumed as hot as 1 150°C, temperatures at the interface between magma and rock salt were calculated at a maximum of 790°C and between 70 and 220°C after one year, depending on the thickness of the dike.[7]

Fig.2, $CO_2$ blow-out feature near dike in IMC potash mine, Eddy County, NM

### II. UNDERGROUND NUCLEAR DETONATIONS

Four underground nuclear tests were detonated between 1961 and 1973 in New Mexico and Colorado (Fig.3) as part of the U.S. government's Plowshare program to investigate civilian and engineering applications of nuclear explosives.[8] As beyond-worst-case engineered analogues they provide useful lessons for geologic waste isolation anywhere. Projects Gnome, Gasbuggy, Rulison, and Rio Blanco caused negligible to undetectable harm to the environment. Surface access to the sites (located in civilian areas, not inside closed military reservations) is unrestricted; surface and adjacent environments are virtually unaffected; and underground land use restrictions are minimal.[9] In short, these sites present no risk to human health or the environment.

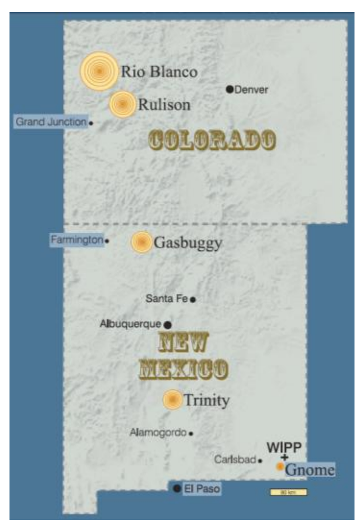


Fig. 3, Nuclear detonations in New Mexico and Colorado (size of circles is proportional to yield)

### II.A. Gnome

Project Gnome, the first Plowshare experiment outside the Nevada test site, detonated December 10, 1961, 360m below the surface 40km southeast of Carlsbad, at the end of a 340m long drift extending laterally from the bottom of a vertical 3m diameter shaft, inside the same massive salt formation that today hosts the Waste Isolation Pilot Plant (WIPP), but in a stratigraphically higher interval (a little more than half as deep). The explosion with a yield of ~3 kilotons was supposed to be completely contained underground, but some steam laced with fission products escaped from the shaft; however, the activity was too low and short-lived to warrant special decontamination measures. The ground above the shot point heaved about 1.4 m, creating shallow surface fractures, and settled back to an elevation of about 0.75 m above the original surface. No radioactive leakage issued from the fractures, and neighboring natural gas well and potash mine operators reported no damage.

The detonation melted ~3 150 tons of rock salt and produced a cavity with a volume of ~27 200$m^3$, ~21 m high with a diameter of >46m (Fig.4).[10]

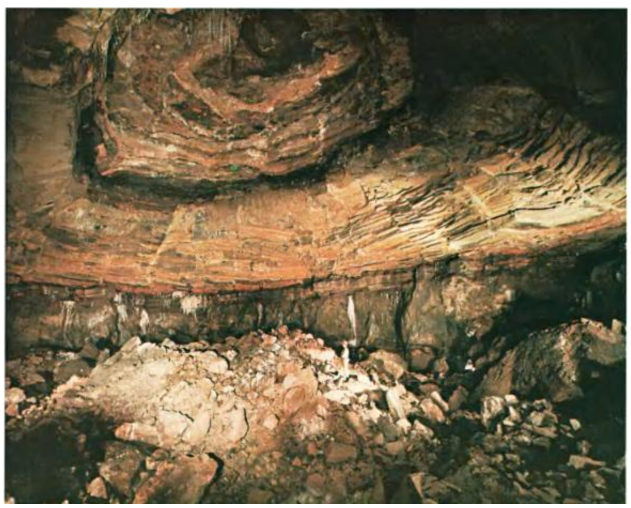

Fig.4, Cavity produced by Gnome detonation and subsequent roof collapse; miner at right center of rubble pile (photo by Lawrence Radiation Laboratory). [10]

Personnel re-entered the cavity May 17, 1962. Decontamination and decommissioning activities in 1979 placed ~36 000 tons of mined salt and other rock into the cavity, filling it to near capacity. The Environmental Protection Agency (EPA) annually monitors 10 wells and 2 municipal water supplies in the vicinity of the site. The Gnome test itself has not caused any well contamination in almost half a century; however, radioactive tracers were introduced into some wells for hydrologic testing, and one well drilled into the shot cavity for tailings disposal was slightly contaminated during decommissioning activities.

### II.B. Gasbuggy

The 29 kiloton Gasbuggy test ~20km southwest of Dulce, NM, took place in deeper (~1 300m) rocks quite different from salt (sandstone) and had quite a different purpose (nuclear instead of hydraulic fracturing of a natural gas reservoir). It caused no measurable harm to humans or the environment either.

## III. DISCUSSION

Bernard L. Cohen advanced a quite convincing (mainly hydrological) argument for the suitability of generic rock to isolate dangerous waste.[11] Almost 40 years of successful geologic isolation of chemically toxic waste in German salt and potash mines strongly suggest that substances even more dangerous (because they have infinite half-lives) than radioactive waste can be disposed of safely. [12]

Beyond-worst-case analogues show clearly that heat-generating materials in the Earth's crust do not necessarily induce undesirable effects in surrounding rocks even at modest distances and without man-made barriers and safety systems. Among the variety of geologic materials, salt has proven in practice to be an effective confinement medium to magmatic intrusions and nuclear detonations.

Thus multiple lines of evidence demonstrate satisfactory confidence in the concept of safe and environmentally compatible final disposal of all kinds of dangerous waste in the subsurface. This practical proof by analogy is actually simpler, cheaper, and more straightforward and realistic than theoretical assumptions, projections, simulations, and models.

## IV. CONCLUSIONS

In light of the recently revived interest in the capability of rock salt to isolate heat-generating radioactive waste in the United States and Germany, the analogues available in southeastern New Mexico have acquired special and fresh relevance. If their lessons and those of other pertinent analogues are not ignored, they can simplify the case for the adequate safety of geologic isolation of all categories of waste in salt.

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